



# A new chemical model of the atmosphere of HD 209458b

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## Abstract

We have created a new model to study the atmosphere of exoplanets. Derived from a car engine combustion model, it is particularly adapted to the high temperature chemistry occurring in the atmosphere of hot Jupiters. Such a model appears essential to interpret recent and future observations, predict the composition and understand the formation and evolution of these planetary bodies. Preliminary results of a 1D thermo-photochemical model for HD 209458b are presented.

## 1. Introduction

HD 209458b is one of the most studied hot Jupiters. This extrasolar giant planet orbits very close from its parent star, at a distance of 0.048 AU. Compared to Jupiter, it receives a high UV flux (10 000 times the flux at the top of the atmosphere of Jupiter) and the temperature of the atmosphere is very high (ranging from 600 K up to 2000 K in the deep atmosphere, corresponding to pressure level greater than 10 bars). The atmospheric composition is thus very influenced by both the high UV flux and the thermochemical processes [1]. In order to interpret correctly the observations of HD 209458b, we need to combine thermochemical reactions to non-equilibrium processes such as vertical transport and photochemical processes [2]. In this view, we have developed two models: a 0D kinetic model, which includes only thermochemical reactions, and a new 1D thermo-photochemical model dedicated to the study of hot Jupiters, in particular HD 209458b.

## 2. Thermo-photochemical model

We use a new chemical scheme including endothermic reactions that are usually neglected when dealing with cooler atmospheres and high temperature kinetics. This chemical network comes from a combustion model developed for car engines [3]. Indeed, the range

of pressure and temperature as well as the main chemical species relevant for hot Jupiters atmospheres are comparable to the conditions found in the combustion processes occurring in car engines. The scheme includes the main hydrocarbons, oxygen and nitrogen compounds (for a total of 172 compounds) linked by 2069 reactions. In order to validate this chemical network, we have created a 0D kinetic model. We have compared the results of this model with the ones from a thermochemical equilibrium model (see Figure 1). We obtain a very good agreement between the two models.

Once the chemical scheme has been validated, we can use it in the 1D thermo-photochemical model, in addition with vertical transport and photolysis processes, which are usually neglected in the studies of hot extrasolar giant planets. The 59 photodissociations added to the validated network are from a model of hydrocarbon photochemistry in Titan's atmosphere [4, 5].

## 3. Preliminary results

We used the solar abundances of C, H, O, N and He as initial conditions for the composition of the atmosphere. Thermochemical processes mainly produce  $H_2$ ,  $H_2O$  and CO which are then transported to higher altitudes. Photodissociation of these same compounds at these altitudes produce H and  $CO_2$ . Comparison with previous models are under study and will be presented in a forthcoming paper [1][6][7][8].

## 4. Perspectives

One significant problem for photochemical models of hot atmospheres is the limited temperature range of available photolysis data. Indeed, most of the photolysis cross-sections available in the literature comes from measurement at ambient temperature ( $T \sim 300$  K). The use of these data for Hot Jupiters models is thus a source of uncertainty. In order to improve our model, we have begun a campaign of measurements

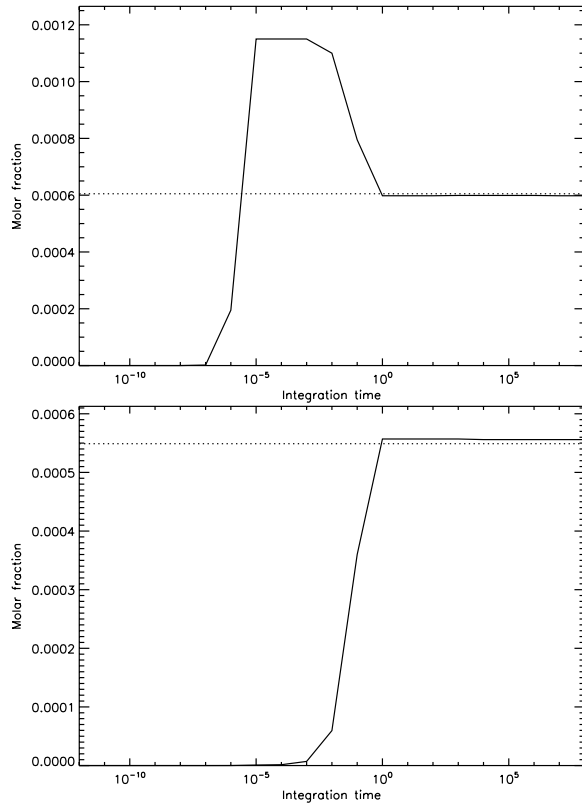


Figure 1: Comparison between the results from a thermodynamical equilibrium model (dotted line) and a kinetic 0D model (solid line), for  $\text{H}_2\text{O}$  (top) and CO (bottom).

of absorption cross sections at high temperature. We use the BESSY synchrotron facilities (Berlin) to generate UV photons from 115 nm to 210 nm. Important species for exoplanet atmospheres such as  $\text{H}_2\text{O}$ ,  $\text{CO}_2$ ,  $\text{CH}_4$  and CO are under study [9].

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